



THE FISHERIES RESOURCES OF LAKE NAKIVALI



Report of a Rapid Assessment of the Lake Nakivali Fishery

Prepared for the Office of the Prime Minister on Lake Nakivali Refugee Settlement.

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Executive Summary

Lake Nakivali is one of the four small lakes that form what is known as the Koki lakes system. It is 14 km long, 6 km wide, 26 km² in area and has maximum depth of 3.5 m at high water level. The lake is located in a lake-swamp complex with River Rwizi as the principle inflow, and a number of peripheral lakes among which are four major ones, i.e. Lakes Nakivali, Mburo, Kachira, and Kijanebalola.

Lake Nakivali is a controlled lake with four official landing sites, namely: Kikusi, Kahirimbi, Kashojwa and Rukinga. The latter three are located within a Refugee settlement whereas Kikusi is outside. The Nakivali Refugee settlement initially established for Rwandese of Tutsi origin in 1963, now has at least seven nationalities which include people from Rwanda, Democratic Republic of Congo, Somalia, Sudan, Ethiopia, Kenya and Eritrea. By the end of 2006, the lake's hinterland of about 378 km² contained 43,448 people of whom 22,448 were refugees. This large population has had stressful impacts on both land and lake resources to the extent that now there is an apparent overfishing on the lake.

Measurements of water quality parameters reveal a change in some of them from the situation that prevailed about 80 years ago. Water clarity (Secchi reading) has dropped from 0.5 to 0.25m and the pH has risen to 9.7 from 7.7. Water temperatures at 25°C have however not changed much. The lake is eutrophic with concentrations of total phosphorus 171 µg L⁻¹, a chlorophyll-a 57.9 and nitrate 25.8 µg L⁻¹. Phytoplankton is dominated by blue green algae, greens and diatoms while benthic organisms consist mainly of molluscs, lakeflies and earthworms (oligochaetes).

Until 1935 when these lakes were stocked with new fish species from other lakes, the lake contained only 5 fish species namely the "Male" (*Clarias gariepinus*), "Nsonzi" (*Clarias wernerii*), *Aplocheilichthys pumilus* and 2 species of "Nkejje" the haplochromines. In addition to the above species the lake currently harbours the Lake Victoria native tilapia *Oreochromis esculentus*, and the stocked Nile tilapia (*Oreochromis niloticus*), *Oreochromis leucostictus* and 4 species of haplochromines. Also present but not mentioned as being one of the indigenous fish species is the "Mamba"/Lungfish (*Protopterus aethiopicus*), an important component of the artisanal fishery on this lake.

Following the introduction of new fish species, annual fish catches from Lake Nakivali rose to a peak of 986 t in 1964 but decreased to 174 t by 1966 and further decline was apparent to the present day. Fishers target 4 fish species namely the haplochromines, *P. aethiopicus*, introduced tilapiines and *C. gariepinus*. These are caught using gillnets and hooks. The haplochromine fishery employs small meshed gillnets (1" to 1½"), the tilapiine fishery utilizes medium sized gillnets (3" and 4") while the *Protopterus* and *Clarias* fishery relies mostly on hooks. In this study, there were 96 canoes all of "parachute" type, each manned by one fisher. 46% of these canoes targeted haplochromines while 40% were fishing for tilapiines. 2906 gillnets were in operation at the gazetted 4 landings in the following proportions: Rukinga (44%) Kashojwa (33%), Kahirimbi (16%) and Kikusi (8%). The bulk (65%) of these gillnets targeted haplochromines.

Highest catch rates were realized by fishers using small meshed gillnets and targeting haplochromines - 15.2 kg/boat/day while the medium sized gillnets targeting tilapiines and some *P. aethiopicus* realised rates of 3.9kg/boat/day. Long-line hooks catching mainly *P. aethiopicus* landed 6.3kg/boat/day.

Overall lake wide catches for September 2010 were estimated at 29.6 t composed of Haplochromines (71.2%), *P. aethiopicus* (16.4%) and *O. esculentus* (7.5%). Other fishes, i.e. *Clarias* spp, *O. niloticus* and *O. leucostictus*, contributed less than 2% of the total catch. *O. esculentus* was the most highly priced fish species followed by *O. niloticus*; haplochromines had the lowest unit price. The lake wide gross landed value of catches for September 2010 was estimated at shs 34 million, distributed amongst the fish species as: haplochromines (65.9%), *P. aethiopicus* (18.4%), *O. esculentus* (9.9%) and approximately 2% for each of other species landed.

Among the two options (cage culture within the lake, and tank aquaculture on the shore) for aquaculture, it is the latter option that looks feasible. Lake Nakivali being so shallow with many floating islands (sudds) and a bottom type of organic mud, may not be suitable for cage culture. Land based tank aquaculture is however a viable option for increasing fish production especially within the refugee settlements. Candidate fish species for culture should be restricted to those already in the system to avoid contamination of the lake with foreign fishes.

Socio- economic information was restricted to the native population outside refugee settlements. It revealed that most adult males interviewed were married and had been on the lake for more than 10 years. The population was mostly illiterate as most of them had not gone beyond primary school. This level of illiteracy was attributed to lack of educational facilities but the situation was improving as many of the school going age group could now access educational facilities provided for refugees.

70% of the population around the lake is involved in fishing. Other activities include agriculture (15%) cattle keeping (10%) and business (5%). Most fishers owned “parachute” type of canoes and fished using gillnets and hooks. The Haplochromis fishery is the most important fishery which employed the majority of the people around the lake. The fishes caught were dried on sticks and sold in places as far away as Masaka and Rakai towns. Respondents were concerned about the dwindling stocks of fish which they attributed to the shrinking size of the lake resulting from human activities in the drainage basin and excess use of water in refugee settlements.

The survey therefore established that Lake Nakivali is a healthy ecosystem capable of sustaining fisheries production. While stock enhancement through restocking with fry could boost fish stocks, especially of the Nile tilapia, effective management measures that allow natural regeneration of stocks of indigenous fish species is paramount. This may require closed fishing seasons and control of fishing effort. Tank aquaculture is a viable option for increasing fish production and Ngege (*O. niloticus*) and Male (*C. gariepinus*) are candidate fish species for fish farming.

1. Introduction.

Lake Nakivali is a small lake, 14 km long, 6 km wide, 26 km² in area and has maximum depth of 3.5 m at high water level (Hughes and Hughes, 1992). The lake is located in a lake-swamp complex with River Rwizi as the principle inflow, and a number of peripheral lakes among which are four major ones, i.e. Lakes Nakivali, Mburo, Kachira, and Kijanebalola. The indigenous fisheries of these lakes were based on *Clarias gariepinus*, *C. wernerii*, and haplochromine cichlids until 1935 when they were stocked with *Oreochromis* spp (e.g. *O. niloticus*, *O. esculentus* and *O. leucostictus*) and other tilapiines e.g. *Tilapia zillii* and *T. rendallii* (Hughes and Hughes, 1992). Annual fish catches from Lake Nakivali rose to 655 t in 1960 and attained a peak of 986 t in 1964 but decreased to 174 t by 1966 (Vanden Bossche and Bernacsek, 1990) and further decline was noted around 1971 (Hughes and Hughes, 1992). This downward trend of catches both the native and introduced fish species appears to have continued to the present day but there are hardly any records of fish catches.

Lake Nakivali is a controlled lake with four official landing sites, namely: Kikusi, Kahirimbi, Kashojwa and Rukinga. The latter three are located within a Refugee settlement whereas Kikusi is outside. The Nakivali Refugee settlement was established in 1963 for Rwandese of Tutsi origin but at present has at least seven nationalities which include people from Rwanda, Democratic Republic of Congo, Somalia, Sudan, Ethiopia, Kenya and Eritrea. The Integrated Rural Development Initiative (IRDI) project in Uganda which is promoting Community Based Environmental Management in Nakivali Settlement in Isingiro district, estimated that 43,448 people composed of 22,448 refugees and 21,000 nationals were living in the area (about 378 km²) in December 2006. The subsistence activities of this large population have had stressful impacts on both land and lake resources. The project seeks to correct this degradation and to support refugees and nationals in using the environment in more friendly and profitable ways. As part of this effort, and following concerns of low fisheries productivity and related environmental issues, the Office of the Prime Minister, through a project on refugee settlement proposed to assess the viability of stocking fish and watershed rehabilitation through tree planting in Lake Nakivali. The project management approached NaFIRRI's for assistance in the following areas:

1. Assessment of Lake Nakivali for re-stocking and watershed planting;
2. Assessment of endemic species in the lake; and
3. Identification of possible Income Generating Projects (IGPs) for the locals and refugees.

2. Survey methodology:

To address the request above, NaFFIRI organised a 5-day rapid assessment of Lake Nakivali starting from 16th September 2010. NaFIRRI constituted the under listed team of five disciplines to address the issues that were in its mandate area.

- i) Water quality and invertebrate productivity;
- ii) Fish diversity, biology, and ecology;
- iii) Fisheries exploitation (fishing effort, fish catches and gross value of the catches)
- iv) Potential for stock enhancement (re-stocking and aquaculture)
- v) Socio-economics of the fisheries

2.1 Assessment of water quality and invertebrate productivity

Dissolved oxygen (mgL^{-1}), temperature ($^{\circ}\text{C}$), pH and water conductivity ($\mu\text{S cm}^{-1}$) were measured *in situ* at 0 m and 0.5 m below water surface using Multiprobe (Hach HQ40d). Field water samples were taken in September 2010 from six transects representative of accessible lake area (Fig. 1) directly by scooping with the white polyethylene sample bottles at 0.5 meter depth. In some instances, surface samples were taken too in a similar manner. Samples were filtered using Whatman GF/C filters. For chlorophyll a analysis, filters were wrapped in aluminium foil for storage until they were delivered to the laboratory. Soluble reactive phosphorus (SRP), nitrate ($\text{NO}_3\text{-N}$), and ammonia ($\text{NH}_4\text{-N}$) were determined by using the ammonium molybdate method (APHA, 1995; Wetzel and Likens, 2000), sodium-salicylate method (APHA, 1995; Müller and Wiedemann, 1955), and indophenol blue method (APHA, 1995; Krom, 1982), respectively. Soluble reactive silica was determined as yellow molybdate-silicic acid (Wetzel and Likens, 2000). The total phosphorus (TP) was determined by persulphate digestion from the aliquots of the samples and analyzed as SRP. Parallel to this, algae samples were taken in 20 mL glass scintillation vials, fixed immediately with three drops of Utermöhl lugol solution and kept under darkness until analysed.



Figure 1. Sampling sites in L. Nakivali

Phytoplankton composition and abundance

Chlorophyll a analysis was based on cold methanol extraction (Stainton et al., 1977). Algae were counted from Lugol fixed samples by using the inverted microscope, as described (Utermöhl, 1958; Wetzel and Likens, 2000). Phytoplankton were identified according to the morphological keys published by Talling (1987), Komarek and Kling (1991), and Komarek and Anagnostidis (1999). At least 400 specimens of the dominant phytoplankton genera were counted at 400× magnification. Most of the genera were counted as single cells [*Anabaena*, *Aphanocapsa*, *Chroococcus*, *Merismopedia*, *Microcystis*; the pennate diatom *Nitzschia* and unidentified centric diatoms, green algae (including desmids) and cryptomonads]. Filamentous phytoplankton was counted as filaments (*Planktolyngbya*, *Pseudanabaena*). The biovolume was calculated based on the measured dimensions of cells/filaments (Hillebrand et al., 1999; Wetzel and Likens, 2000).

Benthic macro-invertebrates sampling and sample processing

Triplicate bottom sediment samples for benthic macro-invertebrates were collected from three stations each showing almost similar sediment type. Ponar grab (Jaw area = 238.0 cm², inner depth = 8.0 cm) was used to collect the sediment samples, as spelt out in standard methods (APHA, 1995). The sediment samples were emptied into plastic basins, their physical characteristics noted e.g. sandy, rocky, etc, and subjected to further processing procedures (APHA, 1995) in order to attain the sorting, identification and quantification of the macro-invertebrates. They were identified using guides to fresh water aquatic macro-invertebrates (Pennak, 1953; Mandal-Barth, 1954; Merrit and Cummins, 1984).

2.2 Assessment of fish diversity, biology, and Ecology

Two fleets of graded mesh multifilament gillnets were set over night in the waters of Bulindi, Katunguru and Kikusi on Lake Nakivali. Each fleet consisted of 9 panels graded at half inch intervals from 1 to 5 inches stretched mesh. One fleet was set inshore next to shoreline macrophytes while the other was in the open water at least 500m from the shoreline. On retrieval fishes caught were removed from the nets, identified/sorted by species, counted and weighed. Species identification was as in Greenwood 1981 for haplochromines and Greenwood 1966 for the non-haplochromine fishes. Data were entered into NaFIRRI catch composition forms to be analysed for fish species diversity and relative abundance.

For each species biometric data were obtained for analysis of sex ratios, gonad maturity state, food and feeding patterns, etc. following the procedures outlined in LVFO (2007).

2.3 Assessment of Fisheries exploitation

2.3.1. Fishing effort

A Frame survey (fisheries census) was carried out at all fish landing sites to establish the total fishing effort by direct enumeration of:

- i) Numbers and types of fishing boats including their size and propulsion;
- ii) The number, type and size of fishing gears used on each boat;
- iii) The kind of fish targeted by each boat; and
- iv) The number of fishers or boat crew that go on fishing trips.

2.3.2. Fish catches

A Catch Assessment Survey (CAS) was conducted at all landing sites. The fish catches at each landing site were recorded on one day. The team carrying out catch assessment reached at each landing site early in the morning well before any fishing boats landed from overnight fishing and stayed up to 11.00 am when all fishing boats were expected to be out of the lake. The byelaws on Lake Nakivali required all fishing boats to be out of the lake by 10.00am. NaFIRRI standard CAS data forms were used to record field data which included: the number, type and size of fishing gears, duration of fishing, and the number, and weight of each fish species caught and mean unit price for each species. Haplochromines from 1"-1.5" mesh size gillnets were weighed together in a basket.

2.3.3 Data analysis

- (i) The Frame survey indicators i.e. Numbers of: fishing boats, fishing gears by type and size, and target fish species were summarized by landing site.
- (ii) The fishing gears were categorized into three effort groups with similar target fish species, i.e. (i) gillnets of 1"-1.5" mesh size; (ii) gillnets of 3"-4" mesh size and (iii) long line hooks. The mean fish catch rates ($\text{kg boat}^{-1} \text{ day}^{-1}$) was estimated for each effort group by species.
- (iii) The total fish catches were estimated using the mean fish catch rates and total effort raising factors determined from Frame survey data. For each effort group, the Boat activity coefficient, i.e. the probability that a fishing boat would be active on any day during the month was estimated as the mean number of days boats in each effort group fished in a week divided by the number of days in a week. The total catch of each effort group was then estimated.
- (iv) The beach value of the catch, i.e. the gross income to the fishers, was estimated by raising the estimated total catch in each effort group by the mean unit price of each fish species landed.
- (v) The mean unit price for haplochromines was derived from weight ratios determined from the mean weight of fish in a bundle (Plate 2.3.1) and the unit prices of bundles. For example a bundle of haplochromines caught with 1" mesh size gillnets contained 120 fish weighting 840g each and sold at shs 900 per bundle. The bundles of catches from 1.5" mesh size gillnets contained 100 fish each weighing 1300g and sold at shs 1500 per bundle.



Plate 2.3.1 Haplochromines caught in 1"-1.5" mesh size gillnets are arranged for sun drying in bundles, which are also units for sale.

2.4 Assessment of potential for stock enhancement

In collaboration with water environment scientists, physico-chemical parameters relevant to cage culture were collected on the lake. These included water depth, dissolved oxygen, lake bottom types, currents etc. Lake shore morphology, drainage and macrophyte type and cover were noted for assessment of possibility of land based aquaculture. Fish prices at the landings were obtained profitability assessment of aquaculture ventures.

2.5 Socio-economics of the fisheries

Field socio- economic data was collected using two major instruments. These included; Key informant interviews (KIIs) for committee leaders and key opinion leader; Focus Group Discussions (FGDs) were conducted with boat owners/ fishers and traders. Topic guides were used to enable gathering of data on the socio- economic factors influencing utilization of the Nakivali fisheries the changing environmental behaviours affecting the Lake overtime.

Data was analysed using the statistical package SPSS for quantitative data and content analysis was used to analyze the qualitative data gathered.

4. Results

4.1 Water quality and invertebrate productivity results

A substantial effort was made in September 2010 in obtaining background data necessary for Lake Nakivale to understand its limnological characteristics and other aspects important for management (Table 1).

4.1.1Physical

The lake exhibit an even depth distribution that at most stations was 1.2m deep. The only exception depth measurement of 2.0m was recorded from Katunguru. This even depth measurement too was reflected in the depth of light penetration that were all in the range of 0.24 to 0.26m from the six stations. Temperature taken at 0.5 m depth in all stations did not vary either; they were all in the range of 24.6°C to the highest of 25.6°C recorded from Middle 1 station. In Katunguru again, the least electrical conductivity (481 μScm^{-1}) was recorded while the highest reading (708 μScm^{-1}) was obtained from Off Landing site station (Table1; Figure 1). The rest of the sites had similar measurements within 500 μScm^{-1} .

4.1.2Chemical

Uniform pH measurements ranging from 9.6 to 9.8 were obtained from the six stations (Table 1). It gave similarity like those from the physical variable. Even with the dissolved oxygen concentration, they were all above 7.0 mgL^{-1} . Off shore 1 gave a slightly higher value of 11.4 mgL^{-1} and the rest of the stations gave varying concentrations that were however not significantly different. For the essential nutrients indicative of the trophic status of Lake Nakivale, total phosphorus concentrations were all greater than 100 μgL^{-1} . The least concentration of 155.6 μgL^{-1} were obtained from the two Off shore stations and the highest concentration of 204.2 μgL^{-1} was recorded from a station just some meters away from the main landing site where there are more fishermen concentrated. Total nitrogen on the other hand ranged from 7200 μgL^{-1} to 8500 μgL^{-1} with it soluble component also detected in considerable amount (Table 1). Base on the geological locality at the foot of volcanic mountain, knowing the silica concentration was paramount. Higher concentrations ranging from 8100 μgL^{-1} in Busenga to 9300 μgL^{-1} in Kayanja-Naruguru were recorded. Basically the differences in measurement were also minimal requiring no statistical test so far.

Table 4.1: Lake Nakivale limnological variables, September 2010

Station	Total depth (m)	Secchi depth (m)	Depth sampled (m)	Temp (°C)	Cond (μScm^{-1})	pH	DO (mgL^{-1})	TP (μgL^{-1})	SRP (μgL^{-1})	TN (μgL^{-1})	NO ₃ -N (μgL^{-1})	NO ₂ -N (μgL^{-1})	NH ₄ -N (μgL^{-1})	SRSi (μgL^{-1})	Chl-a (μgL^{-1})
Off Landing	1.2	0.24	0.5	24.6	708	9.6	9.2	204.4	8.2	8525.6	37.0	7.0	35.9	9060	46.9
Busenga	1.2	0.24	0.5	24.6	567	9.5	7.7	164.4	8.2	7628.2	21.0	4.0	48.3	8100	64.3
Off shore 1	1.3	0.25	0.5	25.6	535	9.7	11.4	155.6	8.2	8461.5	50.0	5.0	41.4	8790	76.5
Off shore 2	1.4	0.25	0.5	24.8	698	9.8	7.3	155.6	10.2	6666.7	18.0	3.0	22.1	9270	60.8
Katunguru	2.0	0.26	0.5	25.6	481	9.7	8.9	173.3	12.3	7307.7	19.0	4.0	24.8	9180	43.4
Kayanja-Naruguru	1.7	0.26	0.5	24.6	579	9.7	8.1	173.3	14.3	8717.9	10.0	3.0	22.1	9360	55.6

Key

Temp = Temperature; Cond = Conductivity; DO = Dissolved oxygen; TP = Total phosphorus; SRP = Soluble reactive phosphorus; TN = Total nitrogen; NO₃-N = Nitrate-Nitrogen; NO₂-N = Nitrite-Nitrogen; NH₄-N = Ammonium-Nitrogen; SRSi = Soluble reactive silica; Chl-a = Chlorophyll-a

4.1.2 Biological

The chlorophyll a an essential variable for providing knowledge of the trophic conditions was high ranging from $43 \mu\text{gL}^{-1}$ in Katunguru station to $76 \mu\text{gL}^{-1}$ in Off shore station 1. The rest of the stations had values in between (Table 1). To investigate to a greater extend, the phytoplankton biovolume estimation via the inverted microscope gave the least biomass of $5.2 \text{ mm}^3\text{L}^{-1}$ in Kayanja-Narugugu and Off landing while the highest biomass of $19 \text{ mm}^3\text{L}^{-1}$ from Off shore 2 (Figure 2). In all station, blue-green algae were the dominant classes with over 70% of the total biovolume. Green algae, diatoms and cryptomonads then followed respectively. A total of 36 phytoplankton species were identified. 15 belonged to blue green algae, 13 green algae, six diatoms and two cryptomonads (Table 2).

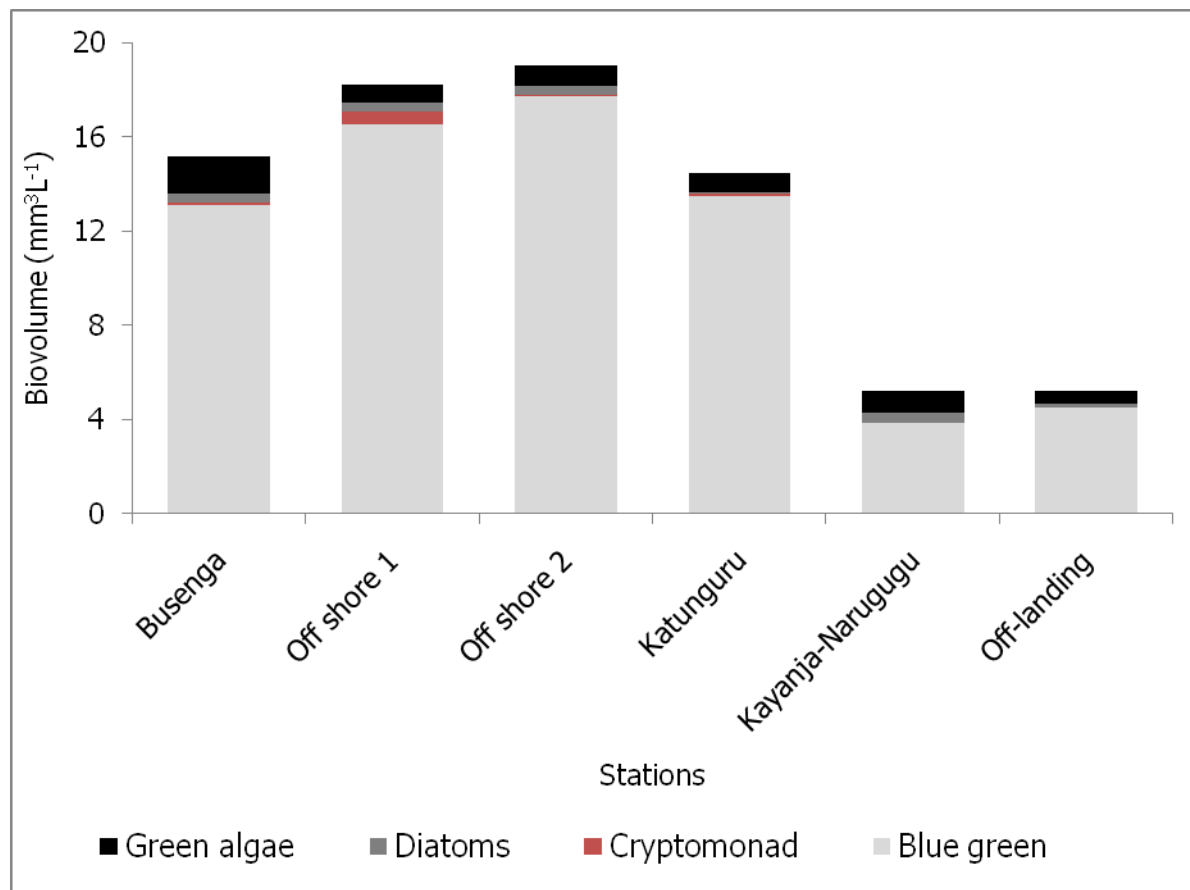


Figure 4.1.1 Phytoplankton biovolume and composition in Lake Nakivali – September 2010.

Table 4.1.2 Phytoplankton species abundance in Lake Nakivali September 2010

Class	Species	Busenga	Off shore 1	Off shore 2	Katunguru	Kayanja-Narugugu	Off landing
Blue-green	<i>Anabaena flos-aquae</i>	√					
	<i>Aphanocapsa delicatissima</i>		√	√	√	√	√
	<i>Aphanocapsa incerta</i>	√					
	<i>Chroococcus dispersus</i>	√	√	√	√	√	√
	<i>Chroococcus limnetica</i>	√	√		√	√	√
	<i>Chroococcus species</i>						
	<i>Coelospherium species</i>	√	√				
	<i>Cylindrospermopsis africana</i>	√	√	√	√	√	
	<i>Merismopedia tenuissima</i>	√	√	√	√	√	√
	<i>Microcystis flos-aquae</i>	√	√		√	√	√
	<i>Microcystis species</i>	√	√				
	<i>Planktolyngbya circumcreta</i>	√	√	√	√	√	√
	<i>Planktolyngbya limnetica</i>	√	√	√	√	√	√
	<i>Romeria gracile</i>					√	
	<i>Snowella species</i>			√			
	Total	11	10	7	8	9	7
Green algae	<i>Ankistrodesmus falcatus</i>	√	√	√	√	√	√
	<i>Ankistrodesmus fusiformis</i>			√		√	√
	<i>Ankistrodesmus setigera</i>	√	√		√	√	√
	<i>Cosmarium depressum</i>		√				√
	<i>Crucigenia apiculata</i>	√				√	
	<i>Monoraphidium contartum</i>	√	√	√	√	√	√
	<i>Pediastrum duplex</i>			√			
	<i>Scenedesmus acuminatus</i>	√	√	√	√	√	
	<i>Scenedesmus acutus</i>	√	√		√	√	√
	<i>Scenedesmus quadricuada</i>	√	√		√	√	
	<i>Scenedesmus species</i>	√		√			
	<i>Tetraedron minimum</i>	√	√	√	√	√	√
	<i>Tetraedron trigonium</i>		√	√	√	√	√
	Total	9	9	8	8	10	8
Diatoms	<i>Aulacoseria ambigua</i>		√	√		√	
	<i>Cyclotephanodiscus species</i>	√	√	√	√	√	√
	<i>Cyclotella species</i>	√	√	√			
	<i>Epithemia turgida</i>	√					

	<i>Nitzschia acicularis</i>	√	√	√	√	√	√
	<i>Nitzschia fonticola</i>					√	
	Total	4	4	4	2	4	2
Cryptomonas	<i>Cryptomonas species</i>	√	√		√		
	<i>Rhodomonas species</i>	√	√	√			
	Total	2	2	1	1	0	0

The macro-benthic community comprised of mollusks, midge larvae and earthworms (oligochaetes). The mollusks were constituted by only one species, *Melanoides tuberculata*, the midges, on the other hand were constituted by two families; the Chironomidae with 4 species (*Chironomus* sp., *Clinotanypus* sp., *Procladius* sp, and *Tanypus* sp.) and Chaoboridae with only one species, the *Chaoborus* sp. (Fig. 1) Whereas the melanoids were recorded at two stations, the chironomids (except *Clinotanypus* and *Tanypus* sp) and chaoborids were recorded at all the sampled stations . The most abundant species was *Chironomus* sp. It was most prominent (322 , 308 and 294 ind. m⁻²) at Katunguru offshore, Katunguru inshore and Kagazi respectively. It had an average density of 221 ind. m⁻² and It was followed by *Chaoborus* sp. 294 and 238 ind. m⁻² still at Katunguru offshore and Busenga offshore respectively. Its mean density was 140 ind. m⁻². The oligochaetes (recovered only at Busenga inshore), registered the least mean density of about 3%. The above results are similar those got from other lakes with this bottom type.

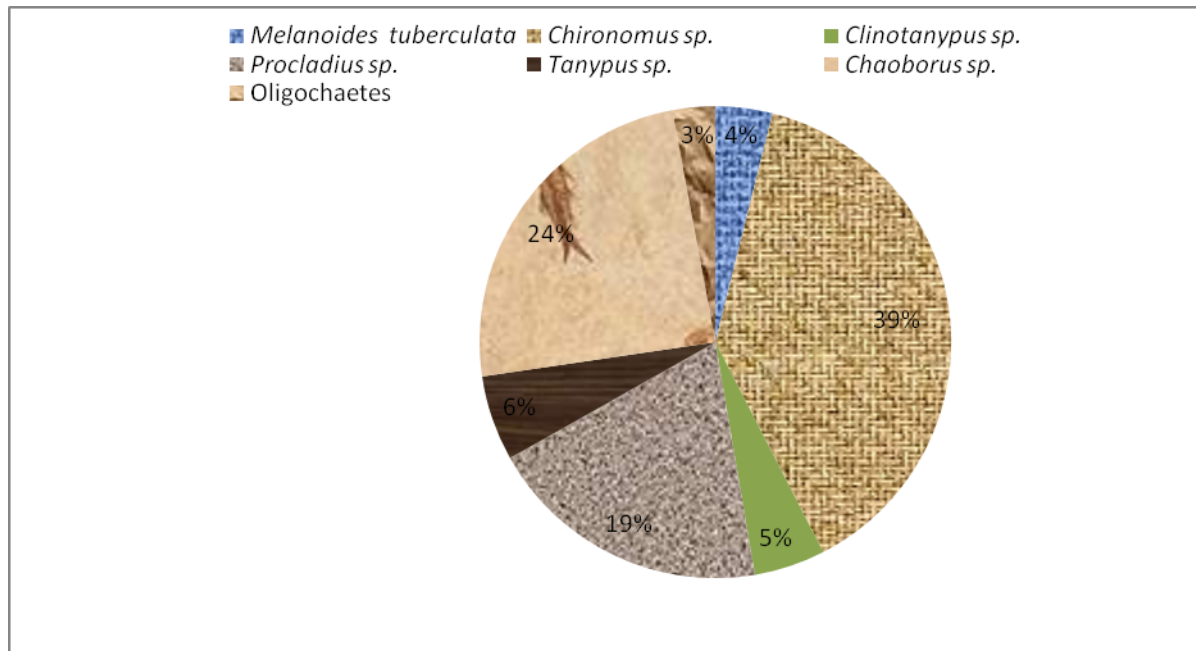


Figure 4.1.2: Percentage composition of macro-benthic organisms in Lake Nakivali, September 2010

Table 4.4: Abundancy of macrobenthos (indiv. m⁻²) at the sampled stations in L. Nakivali, Sept. 2010

Comments Taxa ↓	→ Station about 10m off edge; bottom-decomposing papyrus material	Cloudy (approx 80%); mild wind breeze; bottom- brown fine organic mud (material with decomposing plant deris.	Overcast with a breeze weather; bottom- brown organic material	Overcast weather; bottom- brown organic material	Overcast weather; bottom- brown organic material		
	Busenga inshore	Busenga offshore	Kagazi (centre)	Katunguru inshore	Katunguru offshore	Mean density	
<i>Melanoides tuberculata</i>	42.0	70.0	0.0	0.0	0.0	22	3.9
<i>Chironomus sp.</i>	126.1	56.0	294.1	308.1	322.1	221	38.5
<i>Clinotanypus sp.</i>	0.0	70.0	28.0	28.0	14.0	28	4.9
<i>Procladius sp.</i>	252.1	42.0	56.0	168.1	42.0	112	19.5
<i>Tanypus sp.</i>	0.0	70.0	14.0	84.0	0.0	34	5.9
<i>Chaoborus sp.</i>	84.0	238.1	56.0	28.0	294.1	140	24.4
<i>Oligochaetes</i>	84.0	0.0	0.0	0.0	0.0	17	2.9

4.2 Fish diversity, biology, and Ecology results

4.2.1 Fish species diversity and abundance.

A total of 9 fish species (4 haplochromines and 5 non-haplochromines) were recovered from all areas sampled on the lake. Catches were dominated by cichlids (tilapiines and Nkejje haplochromines). By numbers the haplochromines dominated by *Astatotilapia aeneocolor*. (89%) was the most numerous species while the tilapias *Oreochromis esculentus*, *Oreochromis niloticus* and *Oreochromis leucostictus* followed (8%). Mamba *Protopterus aethiopicus* (2%) was third. The other fish species of commercial importance, Male *Clarias gariepinus* contributed 0.25%. By weight, the order of importance was Mamba (45%), the Nkejje (30%) and the tilapias (25%) (Table 4.2.1).



Ngege *Oreochromis esculentus*



Nile tilapia *Oreochromis niloticus*



Male *Clarias gariepinus*



Mamba *Protopterus aethiopicus*

Plate 4.2.1 Common no-haplochromine species found in Lake Nakivali

Four haplochromine species belonging to three genera were identified from the lake (Plate 4.2.2). They were dominated by the genera *Astatotilapia* and *Harpagochromis*.



Astatotilapia aeneocolor



Harpagochromis "red-top"



Harpagochromis squamipinnis



Gaurochromis sp

Plate 4.2.2 Haplochromine species of Lake Nakivali

Table 4.2.1 Fish species caught by experimental gillnets from different sampling stations on Lake Nakivali in September 2010

FAMILY	Species	NUMBERS			
		Bulindi	Katunguru	Kikusi	Total
Cichlidae	<i>Astatotilapia sp</i>	27.41	22.08	14.72	64.21
	<i>Gaurochromis sp</i>	0.00	0.51	0.25	0.76
	<i>Harpagochromis "red top"</i>	0.00	5.33	1.78	7.11
	<i>Harpagochromis squamipinnis</i>	13.71	1.52	2.03	17.26
	<i>Oreochromis esculentus</i>	1.52	2.28	3.55	7.36
	<i>Oreochromis leucostictus</i>	0.25	0.00	0.00	0.25
	<i>oreochromis niloticus</i>	0.00	0.51	0.00	0.51
	<i>Clarias gariepinus</i>	0.00	0.00	0.25	0.25
Clariidae					
Lepidosirenidae	<i>Protopterus aethiopicus</i>	1.02	0.51	0.76	2.28
	Total	43.91	32.74	23.35	100

FAMILY	Species	WEIGHT			
		Bulindi	Katunguru	Kikusi	Total
Cichlidae	<i>Astatotilapia sp</i>	5.37	3.10	2.61	11.09
	<i>Gaurochromis sp</i>	0.00	0.23	0.11	0.35
	<i>Harpagochromis "red top"</i>	0.00	3.33	0.94	4.26
	<i>Harpagochromis squamipinnis</i>	11.44	1.08	1.76	14.28
	<i>Oreochromis esculentus</i>	1.88	3.97	13.68	19.53
	<i>Oreochromis leucostictus</i>	1.04	0.00	0.00	1.04
	<i>Oreochromis niloticus</i>	0.00	4.27	0.00	4.27
	<i>Clarias gariepinus</i>	0.00	0.00	0.36	0.36
Clariidae					
Lepidosirenidae	<i>Protopterus aethiopicus</i>	13.07	8.17	23.60	44.84
	Total Weights	32.80	24.15	43.06	100

4.2.2 Catch rates of experimental gillnets

Catch rates, calculated as numbers or weight of fish per net per night was calculated bearing in mind the maximum size the species tends to grow. Fish species were categorized as “A” small sized species, “B”. Medium and “C” large sized fish species. Category A was calculated using nets up to 2.5 inches, category B up to 4.5 inches and category C, all the nets set.

Haplochromines recorded the highest catch rates both by numbers and weight (Table 4.2.2). Bulindi waters yielded the highest rates by numbers (9.61 fish per net per night) while by weight Kikusi led the way with 470.44 g of fish per net. Fish species that dominate the fishery on this lake also dominated in abundance.

Table 4.2.2 Catch rates of fish species from different stations sample by experimental gillnets on Lake Nakivali September 2010.

Species	Category	NUMBERS			
		Bulindi	Katunguru	Kikusi	Overall
<i>Clarias gariepinus</i>	C	0	0	0.06	0.02
Haplochromines	A	20.25	14.50	9.25	14.67
<i>Oreochromis esculentus</i>	B	0.38	0.56	0.88	0.60
<i>Oreochromis leucostictus</i>	B	0.06	0	0	0.02
<i>Oreochromis niloticus</i>	C	0	0.11	0	0.04
<i>Protopterus aethiopicus</i>	C	0.22	0.11	0.17	0.17
Total Numbers		9.61	7.17	5.11	7.30

Species	Category	WEIGHT (g)			
		Bulindi	Katunguru	Kikusi	Overall
<i>Clarias gariepinus</i>	C	0	0	3.89	1.30
Haplochromines	A	413.25	190.31	133.25	245.60
<i>Oreochromis esculentus</i>	B	23.13	48.75	168.13	80.00
<i>Oreochromis leucostictus</i>	B	12.75	0	0	4.25
<i>Oreochromis niloticus</i>	C	0	46.67	0	15.56
<i>Protopterus aethiopicus</i>	C	142.78	89.22	257.89	163.30
Total Weight		358.33	263.81	470.44	364.19

4.2.3 Fish biology and ecology.

A total of 44 fish specimens (one *C. gariepinus*, 30 *O. esculentus*, one *O. leucostictus*, one *O. niloticus* and 10 *P. aethiopicus*) were examined for biological parameters. Analysis was therefore restricted to more numerous species namely *O. esculentus* and *P. aethiopicus*.

Size of *O. esculentus* examined ranged from 7.2 to 20.1cm Total Length (TL). There were 17 females and 13 males. Females matured at a slightly smaller size (15cm TL) than males (16cm TL). Fulton's condition factor (K), a measure of the well-being of the fish was slightly higher among females (mean 1.62) compared to males at a mean of 1.57. 50% of the mature females and all mature males were in breeding condition. Out of the 30 stomachs of *O. esculentus* examined, only 6 contained food material. The species fed on Algae with blue /greens dominating, detritus, rotifers, insect remains and higher plant material Table 4.2.2.

10 specimens (7 females and 3 males) of "Mamba" (*P. aethiopicus*) were examined. Their size ranged from 23.5 to 82.9cm Anal Length (AL). Mean

Condition factor was calculated at 0.34 for males and 0.33 for females. All fishes measuring 37cmAL were mature.

7 of the 10 stomachs examined contained food. The species fed on detritus, molluscs and fish (Table 4.2.3)

Table 4.2.3 Percent contribution of food items in the diet of *O. esculentus* *O. niloticus* and *P. aethiopicus* in Lake Nakivali (HPM = Higher plant material)

	Detritus	HPM	B/green	Green	Diatom	Rotifer	Insect	Fish	Mollusk
<i>O. esculentus</i>	21.9	0.6	59.9	11.1	3.1	2.3	1.1		
<i>O. niloticus</i>	10	50	25	10	3	2			
<i>P. aethiopicus</i>	38.7							25.8	35.5

4.2 4.3 Fisheries exploitation

4.2.1 4.3.1 Fishing effort

There were 96 fishing boats at the four official landing sites (Table 4.3.1). All boats were of similar type, i.e. flat bottom planked canoes (*parachutes*) propelled by paddle. The number of boat crew was equivalent to the number of fishing boats because all boats went fishing by one person. The main fishes targeted were haplochromines and tilapiines in which 46% and 40% of all active fishing boats were operating, respectively. The remaining 14% of boats were targeting *Protopterus aethiopicus* and *Clarias* spp. Only two types of fishing gears, i.e. gillnets and long line hooks were encountered in the lake. A total of 2,906 gillnets were in use, and were distributed in the landing sites as follows Rukinga (44%) Kashojwa (33%), Kahirimbi (16%) and Kikusi (8%). A large proportion (61%) of gillnets were of 1 inch mesh size. Another 4% of gillnets were of 1.5 inch mesh size. The two mesh sizes were used to target haplochromines, a fishery in which 46% of active fishing boats were operating whereas the larger gillnets (3 to 4 inch mesh size) were used to target tilapiines (Table 4.3.2). The boats using long line hooks targeted *P. aethiopicus* and *Clarias* spp.

Table 4.3.1 Number of boats targeting different fish taxa

Item	Landing site name				
	Kahirimbi	Kashojwa	Kikusi	Rukyinga	Total
Number of fishing boats	19	32	13	32	96
Number of crew**	19	32	13	32	96
No. of boats targeting different fishes					
Haplochromines	7	14	4	19	44
Tilapiines	8	12	9	9	38
<i>Protopterus</i> sp.		6		4	10

<i>Clarias</i> sp.	4				4
Number of fishing gears					
1" mesh size gillnets	306	463	80	930	1,779
1.5" mesh size gillnets				110	110
3" mesh size gillnets	95	480	97	136	808
3½" mesh size gillnets	30			65	95
4" mesh size gillnets		3	50	31	84
4½" mesh size gillnets	30				30
Total gillnets	461	946	227	1,272	2,906
Long line hooks	1,240	1,300		1,100	3,640

**The each fishing boat went fishing with one fisher (crew)

Table 4.3.2 Number of gears by type and/or size targeting different fish taxa

	Fish species				
Gear type/size	Haplochromines	Tilapiines	<i>Protopterus</i>	<i>Clarias</i>	Grand Total
1" mesh size gillnets	1779				1779
1.5" mesh size gillnets	110				110
3" mesh size gillnets		808			808
3½" mesh size gillnets		95			95
4" mesh size gillnets		84			84
Long line hooks			2400	1240	3640

4.3.2 Fish catch rates

Fishing boats using gillnets of the smallest mesh size range (1"-1.5") landed only haplochromines and had the highest catch rates of 15.2 ± 4.6 kg/boat/day (Figure 4.3.1, Plate 4.3.1). Boats using gillnets of 3"-4" mesh size landed mainly *P. aethiopicus* (2.1 ± 0.8 kg/boat/day) and *Oreochromis esculentus* (1.8 ± 0.7 kg/boat/day). The latter boats also landed *Clarias* spp, *O. leucostictus*, and *O. niloticus* but in insignificant quantities (≤ 0.5 kg/boat/day). The boats using long line hooks landed mainly *P. aethiopicus* (6.3 ± 5.2 kg/boat/day) and small quantities of *Clarias* spp and *O. esculentus* (0.2 and 0.5 kg/boat/day, respectively).

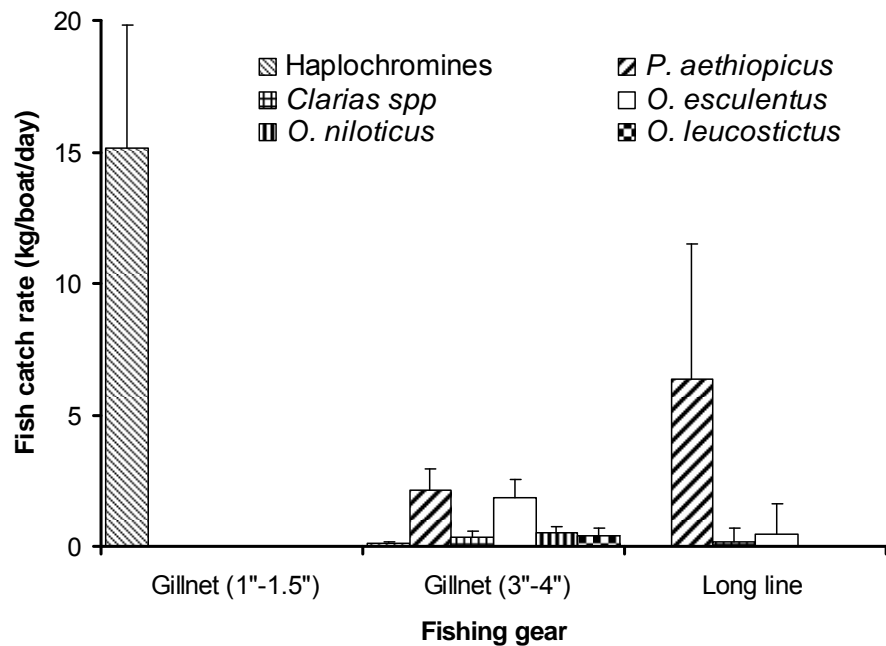


Figure 4.3.1 Fish catch rates of fishing boats using long line hooks and gillnets of 1"-1.5" and 3"-4" mesh size (error bar = 95%CL).



Plate 4.3.1 Family members removing haplochromines from 1" mesh size gillnets at Kahirimbi landing site. This was the largest fishery on Lake Nakivali in September 2010.

4.3.3 Size composition of the catches

The size of individual tilapias in the catches of fishers ranged from 16 to 32 cm Total Length (TL) with a mean length of 21.7 cm TL for *O. niloticus*; 15 to 23 cm TL and mean length of 18.7 cm TL for *O. esculentus*; and 15 to 24 cm TL with mean length of 18.9 cm TL for *O. leucostictus* (Figure 4.3.2). A wide range of sizes of *P. aethiopicus* from 43 to 105 cm was also encountered in the catches.

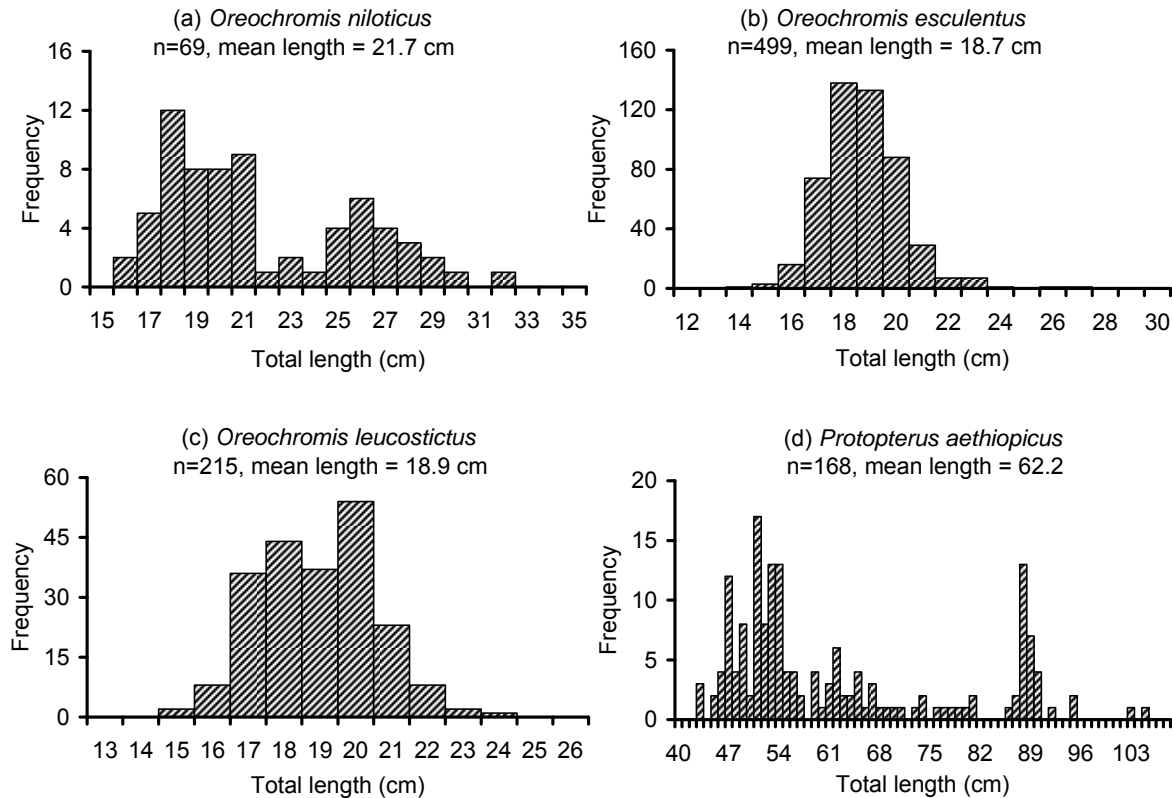


Figure 4.3.2 Size composition of commercial fish catches on Lake Nakivali in September 2010 excluding haplochromines and *Clarias* spp which were not separated into individual species, (a) *Oreochromis niloticus*, (b) *Oreochromis esculentus*, (c) *Oreochromis leucostictus*, and (d) *Protopterus aethiopicus*.

4.3.4 Total catch estimates

The fishery with 1"-1.5" mesh size gillnets had the highest total catch (20.9 t) for September 2010 followed by boats using 3"-4" mesh size gillnets (5.9 t) and those using long line hooks had the lowest catches (2.7 t)(Tables 4.3.3-5). The catches of 1"-1.5" mesh size gillnets were exclusively haplochromine cichlids, while those of 3"-4" mesh size gillnets contained the highest variety of fishes dominated by *Oreochromis* spp. Long line total catches were dominated by *P. aethiopicus* (2.5 t out of 2.7 t). The overall lake wide catches for September 2010 were estimated at 29.6 t composed of Haplochromines (71.2%), *P. aethiopicus* (16.4%) and *O. esculentus* (7.5%) (Table 4.3.6). Other fishes, i.e. *Clarias* spp, *O.*

niloticus and *O. leucostictus*, contributed less than 2% of the total catch. 37.8% of the catch was at Rukinga landing site followed by Kashojwa (33.3%), Kahirimbi (17.9%) and least at Kikusi landing site (11%).

Table 4.3.3. Contribution to total month catches by boats using 1"-1.5" mesh size gillnets on Lake Nakivali for September 2010

	Landing site				
Fish species	Kahirimbi	Kashojwa	Kikusi	Rukyinga	Total
Haplochromines	3,185.8	6,826.8	1,820.5	9,102.4	20,935.4

Table 4.3.4. Contribution to total month catches by boats using 3"-4" mesh size gillnets on Lake Nakivali for September 2010

	Landing site				
Fish species	Kahirimbi	Kashojwa	Kikusi	Rukyinga	Total
<i>O. niloticus</i>	119.0	163.7	133.9	133.9	550.6
Haplochromines	26.0	35.7	29.2	29.2	120.1
<i>P. aethiopicus</i>	512.2	704.3	576.2	576.2	2,369.0
<i>Clarias spp</i>	85.9	118.1	96.6	96.6	397.1
<i>O. leucostictus</i>	100.4	138.1	113.0	113.0	464.5
<i>O. esculentus</i>	437.5	601.6	492.2	492.2	2,023.4
Total	1,281.0	1,761.4	1,441.1	1,441.1	5,924.7

Table 4.3.5 Contribution to total month catches by boats using long line hooks on Lake Nakivali for September 2010

	Landing site				
Fish species	Kahirimbi	Kashojwa	Kikusi	Rukyinga	Total
<i>P. aethiopicus</i>	760.5	1,140.8	-	570.4	2,471.6
<i>Clarias spp</i>	24.0	36.0	-	18.0	78.0
<i>O. esculentus</i>	57.0	85.5	-	42.8	185.3
Total	841.5	1,262.3	-	631.1	2,734.9

Table 4.3.6 Overall total catch (kg) for one month on Lake Nakivali for September 2010

	Landing site				
Fish species	Kahirimbi	Kashojwa	Kikusi	Rukyinga	Total
Haplochromines	3,211.8	6,862.5	1,849.7	9,131.6	21,055.5
<i>P. aethiopicus</i>	1,272.7	1,845.0	576.2	1,146.6	4,840.6
<i>Clarias spp</i>	109.9	154.1	96.6	114.6	475.1
<i>O. esculentus</i>	494.5	687.1	492.2	534.9	2,208.7
<i>O. niloticus</i>	119.0	163.7	133.9	133.9	550.6
<i>O. leucostictus</i>	100.4	138.1	113.0	113.0	464.5
Total	5,308.3	9,850.4	3,261.6	11,174.6	29,595.0

4.1.5 Gross value of catches

Oreochromis esculentus was the most highly priced fish followed by *O. niloticus* and haplochromines had the lowest unit price (Table 4.3.7). The lake wide gross landed value of catches for September 2010 was estimated at shs 34 million, distributed amongst the fish species as follows: haplochromines (65.9%), *P. aethiopicus* (18.4%), *O. esculentus* (9.9%) and approximately 2% for each of other species landed (Table 4.3.8). Rukinga landing site had the highest share of the gross revenue from landed catches, i.e. shs 12.6 million (36.8%) followed by Kashojwa (33%), Kahirimbi (18.4%) and least at Kikusi (11.5%).

Table 4.3.7 The average unit price (shs/kg) of fish landed from Lake Nakivali for September 2010

Fish species	Price
Haplochromines	1077
<i>P. aethiopicus</i>	1304
<i>Clarias spp</i>	1239
<i>O. esculentus</i>	1538
<i>O. niloticus</i>	1444
<i>O. leucostictus</i>	1260

Table 4.3.8 Total gross revenue from the catches (shs) for one month on Lake Nakivali for September 2010.

Fish species	Landing site				
	Kahirimbi	Kashojwa	Kikusi	Rukyinga	Total
Haplochromines	3,449,470	7,370,301	1,986,568	9,807,309	22,613,648
<i>P. aethiopicus</i>	1,659,618	2,405,937	751,417	1,495,186	6,312,158
<i>Clarias spp</i>	136,125	190,889	119,687	141,989	588,690
<i>O. esculentus</i>	760,531	1,056,688	756,973	822,722	3,396,914
<i>O. niloticus</i>	171,894	236,354	193,380	193,380	795,009
<i>O. leucostictus</i>	126,538	173,989	142,355	142,355	585,236
Total	6,304,175	11,434,158	3,950,380	12,602,942	34,291,655

4.4 Assessment of potential for stock enhancement - results

Definitely the supply of fish from Lake Nakivali is very important for the livelihood of the community but it is not sufficient. Some little improvement could be achieved by improving the management but only a little improvement. Aquaculture offers the greatest potential for significant improvement in fish supply. Two options for aquaculture production are discussed, namely cage culture within the lake, and tank aquaculture on the shore.

4.4.1. The cage option

The most important requirements for cage culture include the following conditions:-

- i. a minimum water depth greater 4 M,
- ii. notable water current
- iii. a clear, hard and smooth water bottom without any depressions, caves or outcrops,
- iv. a water bottom with a minimum of organic materials,
- v. a clear water body without any moving sudd.

The measurements of these parameters showed the following:-

- i. That the maximum water depth throughout the entire lake was less than 2 M (not even enough to take the depth a cage),
- ii. The lake bottom is full of organic material not capable of taking any more organic material resulting from feeding a concentrated population of fish in a cage,
- iii. The lake is badly infested with moving papyrus sudds / islands that easily damages cages.

For these and other reasons, Lake Nakivali is not suitable for cage aquaculture.

4.4.2 The pond and Tank options

The pond or tanks options using the lake as the water source are suitable. However, the economics of pumping water from the lake favours only the intensive, high productivity tank system. The most effective arrangement is establishing several tanks (eg. each of dimensions 2 x 5 x 1.5 M) at each settlement. Water would be pumped from the lake into the tanks for growing fish intensively (up to 200 fish per M³), the fish being fed on commercial feed. This high stocking rate will require frequent water exchange (water coming in and flowing out). But the feed – and waste product- laden water would be subjected to bio-filtration before either returning to the lake or collecting it into the sump for re-use in the fish production tanks. By this method, productivity of as high as 150 kg/m³ of tank can be achieved. Catfish and tilapia are the best candidates for this kind of system. The fish species native to the lake would be cultured to avoid contamination of the lake with foreign fish in case of the likely escapes from the tanks.

A catfish and a tilapia hatchery would be established at a convenient point along the lake to supply the catfish and tilapia farms.

4.4.3 Way Forward

The way forward for aquaculture is to prepare a concept or project proposal and market it to funders for funding.

4.5 Socio-economics of the fisheries - results

Information about the current socio- economic status of fisheries activities around Lake Nakivali was collected and analyzed. Four landing sites namely; Kayilimbi, Kikusi, Rukinga and Kashojjo were visited. Most respondents were male adults with a mean age of 33.18 years. Most (78.8%) were married and had been around the Lake for 10.5 years averagely. All the respondents were Uganda national as the law prohibits refugees getting involved in fishing. However two female adults were encountered dealing in fish trading activities.

Most fishers (69.7%) had only acquired primary level of education while (27.3%) had not been to school at all. This level of illiteracy around Lake Nakivali has been due to lack of educational facilities in the area. However there has been improvement in infrastructure developments that could enhance and improve on the education levels as a result of the interventions of Government of Uganda (GoU) in partnership with the United Nations High Commission for Refugees (UNHCR).

Characteristics of operating units and Fish marketing

All the respondents owned parachute boats which they used for fishing. In a few cases, fishers shared the boat each with own fishing gears. The average Length overall (LOA) was 13ft. Most fishers (93.9%) used gillnets with a mean of 25 nets in each boat and ranging between mesh size 1 to 4 inches. Only (6.1%) used hooks ranging between number 7 and 9. Most fishers (57.6%) targeted Haplochromines. Others, (36.4%) targeted the different tilapia species. Only (6%) targeted *Protopterus*. Haplochromis fishery is the most important fishery which employed the majority of the people around Lake Nakivali. The fishers (boat owners) do the fishing (production) and also engage in processing and marketing of the final product. During the survey, one fish trader who bought in bulk was encountered. He collected the dried haplochromines from individual fishers and

transported it to areas like Masaka and Rakai where he also wholesaled to other retailers. Catches of these haplochromines varied significantly and poor seasons were majorly experienced during the rainy season.

Fish Species	Valid Percentage (%)
Haplochromines	57.6
Tilapia Spp	36.4
<i>Protopterus</i>	6.0
Total	100.0

Livelihood Sources/ Activities

Information gathered indicates that people around the Lake (70%) were majorly involved in fishing as their main source of livelihood. These are the nationals like Bakiga, Banyankole and Baganda. No refugee was reported to be fishing as the law does not allow them to do so. Others, (15%) were involved in agriculture which was practiced by both the nationals and the refugees. Only (10%) were involved in animal rearing and (5%) in small businesses.

Effect of the Activities on the Fisheries Resource

The fisheries resources were being threatened by reduction (receding) in the size of the Lake as a result of siltation (soil erosion from hills) and encroachment on the wetlands surrounding the Lake in search for agricultural land. Land is cleared for cultivation, settlements and also through grazing of animals which contribute to soil erosion.

River Lwizi which was a major water feeder into Lake Nakivali was reported to have been diverted by the Lake Mburo national park authorities. This has caused a significant reduction in the volume of water entering into Lake Nakivali. Further still, before its diversion, the river had a lot of deposits in its mouth which could not allow enough water to flow into the Lake.

It was also reported that pumping of water for domestic use by the UN agency; IGTZ of about 480,000 litres everyday was a major contributor to the receding of

the Lake. There are also other water users like animals and households which can consume up to about 100,000 litres on a daily basis as reported by one of the respondents.

Changes in climatic conditions were reported to have contributed to the receding of the Lake. Respondents said that they are now experiencing long drought periods than before which have also affected food production and environmental degradation.

Constraints/ Concerns

Most fishers (78.8%) complained about the floating suddes as the major problem affecting their fishing activities as they carry away the fishing gears or entangle them. This makes fishers meet costs of replacements frequently or repair the nets. Other constraints reported included seasonality changes (9%) and threats from crocodiles and Hippos (3%). Fishers also raised the issue of lack of clean water for domestic use. Communities around the Lake use water from the Lake as they have no access to any clean water source. This has exposed them to many water borne diseases.

There are no Government medical facilities around the Lake. Fishers had to move long journeys to access medical services. However some fishers reported that they accessed medical services provided by the UNHCR.

Land disputes between the nationals and the refugees was a major concern among the fishers. Interests in land vary from the need for land for food production, animal grazing to space for infrastructural development like housing.

Governance

The fishing communities around Lake Nakivali are governed by what they refer to as task force committees. These committees comprise of four elected members and headed by what they refer to as the fish guard. This governance was especially on landings Kayilimbi, Kikusi and Rukinga. However there was some knowledge about Beach management units (BMUs) at Kashojjo Landing site. All the respondents at this landing site mentioned of the existence of a BMU. However they had no knowledge of the requirements of putting up a BMU.

5 Discussion

5.2 Fish species diversity, biology and ecology

Historical information on the fisheries of Lake Nakivali indicate that up to the 1930s *Clarias* spp and Haplochromines were the major fish species supporting the fisheries (Hughes and Hughes, 1992; Worthington, 1932). Fish species present then included *Clarias gariepinus* (*C. Mossambicus*), *Clarias wernei* and *Aplocheilichthys pumilus* (Worthington 1932). Although all these species are still present in the lake, our survey recovered only *C. Gariepinus* among them. A specimen of *C. wernei* was seen among the artisanal catches. The gear used (gillnets) could not recover *A. pumilus*, a species too small to be caught by gillnets used. Among the haplochromines the report identify *Astatotilapia nubila* (*Haplochromis nubilus*,) *Pseudocrenilabrus multicolour* (*Hemihaplochromis multicolour*) and *Astatoreochromis alluaudi*. Although these species have been recovered from other Koki lakes (NaFIRRI Reports), they were not among the haplochromines identified during this survey. It is possible that at that time in the past, all the smaller sized *Astatilapia* spp were identified as *H. nubilus* bearing in mind that most haplochromines turn black on death. Failure to mention the predatory *Harpagochromis* species common in these lakes suggests that they were indeed not present but could have been introduced together with the tilapias especially the non-Victorian tilapiines *O. niloticus* and *O. leucostictus*. These Hapagochromis species are of the George/Edward origin.

Catch rates by experimental gillnets of 364.2g per net per night are comparable with rates obtained in similar small lakes. On Lakes Nakuwa and Nawampasa both in the Kyoga basin, surveys show catch rates of 321.1g and 198.8g per net per night respectively (NaFIRRI 2010). Rates for haplochromines (245g) are even much higher than in Lake Nawampasa (84.1g) where the species is not commercially exploited.

The earlier reports did not list *Protopterus aethiopicus* among the introduced fishes and it was found to be one of the important fisheries in the lake. Elders interacted with at landing sites during this study indicated that the species was native. The lake, together with other small lakes in the region (e.g. Kijanebalola, Kachira, and Mburo) were stocked with a variety tilapias in 1935 to increase production of desirable large table fishes (Hughes and Hughes, 1992).

Biological information has remained comparable with earlier information on the nearby lakes within the Koki Lakes system (Nagayi Kalule 1999). Table 5.1 shows some biological parameters of *O. esculentus* calculated from data collected during this survey as compared with those obtained in 1999.

Table 5.2 Biological parameters of *Oreochromis esculentus* in three Koki lakes.
(* from Nagayi Kalule 1999.)

Water body	Biological parameter			
	Condition Factor (K)	Size at 1 st maturity (TL cm)	Sex ratio (M:F)	Main food type
Lake Kachira*	1.85	17	0.79	Blue/green algae
Lake Mburo*	1.83	16.8	1.5	Blue/green algae
Lake Nakivali	1.62	15 -16	1.3	Blue/green algae

The food of Mamba *P. aethiopicus* (Mollusks, detritus and fish) has remained consistent with what is in literature (Greenwood 1066).

5.3 Fisheries exploitation

The earliest available fish catch statistics indicated an annual fish production of 655 t in 1960, which increased to peaks of 895 t and 986 t in 1962 and 1964 respectively (Vanden Bossche and Bernacsek, 1990). Although the species composition of the catch is not in the literature, the high production in the early 1960s is likely to have been from a vibrant fishery of introduced tilapias. The same data set indicates that annual catches reduced to 109 t and 274 t in 1965 and 1966 respectively. This period coincided with the establishment of the Nakivali Refugee settlement in 1963. The influx of Rwandese refugees into the settlement in 1963 is likely to have resulted in rapid increase of fishing pressure on the lake leading to the highest catches in 1964 and a collapse of the fisheries soon after.

The current study estimated production of 30 t of fish for one month (September 2010), implying that annual fish catches were in the region of 360 t assuming limited seasonal fluctuations. The dominant component of the catch (71%) was contributed by native small haplochromine cichlids and *P. aethiopicus* (16%). The introduced tilapias were occasionally encountered in the catches. Like many exploited inland fisheries globally, the fishery of Lake Nakivali appears to have undergone the classic fishing down process (Welcomme, 1999) whereby the fish biomass in a water body shifts from large sized fish to small sized species in the face of increased fishing pressure. In most inland fisheries, individuals species may be overfished and disappear from the fishery but the assemblage as a whole continues to produce at high level, albeit fish which may not have the same quality as those that have disappeared. Secondly a fishery based on small sized fast growing species can absorb greater amounts of fishing effort than a fishery concentrating on only large species in the assemblage.

Three basic strategies for management of fisheries (Welcomme, 1999) can apply to Lake Nakivali.

1. To manage the fishery only for large species of high commercial value.
This implies accepting less maximum yield in terms of absolute tonnage although the value of the catch may offset this. It requires strict control of gillnet mesh sizes which are the main gear on the lake; control of effort, e.g. the number of boats, gears and duration of fishing. It also needs severe restrictions on exploitation fisheries of smaller fishes.
2. To maximise yield but conserve the fish assemblage.
This requires rigid enforcement of regulations on both mesh size and access. It also requires banning of gears and fishing methods that impact species of smaller size or establishment of closed seasons and/or closed areas. This degree of control is liable to introduce social inequalities.
3. To allow the fishery to continue being fished-down.
Such a decision is made for social reasons rather than the fishery resource. This may be disastrous because it can leave the fish fauna permanently damaged.

When fisheries become fished down to the extent that favoured species are severely reduced in abundance, there is a tendency to compensate either by stocking to maintain the target species, or by introducing other species which may resist exploitation pressure better. In the case of Lake Nakivali, The Integrated Rural Development Initiative (IRDI) project through UNHCR-Nsamizi Nakivali Project has sought to assess the viability of stocking fish in the lake. In this case, the favoured species are probably the tilapiines and other species like *Clarias* that grow to large sizes in place of the seemingly abundant haplochromines. Three basic questions need to be asked need to be answered:

- (i) Will re-stocking/stocking will recover and sustain the fisheries?
- (ii) Will re-stocking/stocking ensure sustainable food supplies and observance of the increasing importance of biodiversity?
- (iii) Can the improvement of management practices rehabilitation degraded lake ecosystems and faunal assemblages be enough to recover the fisheries?

Already there was evidence of good management practices that have probably helped to maintain the existing haplochromine fishery in the lake, the key one being restriction on fishing time and elimination of active fishing methods, i.e. fishing was limited to overnight fishing with passive fishing gears. No boat was allowed on the lake beyond 10.00 am and seines had been outlawed from the lake. The landing sites were also restricted to only four that are easy to monitor. This could make a starting point upon which fishing effort could be scaled down by:

- (i) Removing some boats from the lake;
- (ii) Making all boats fish for shorter periods;
- (iii) Limiting the amount or size of gear that a boat can carry; and/or
- (iv) Reducing the efficiency of fishing effort (e.g. by closing areas where catch rates are high or closing some fishing seasons).

These measures will be required even when re-stocking/stocking has been undertaken in order to avoid overfishing.

6. Conclusions and recommendations

6.2 Fish species diversity, biology and ecology

Results obtained from this survey indicate that Lake Nakivali, just like the other lakes in the Koki lakes system is poor in fish species diversity. The situation would have been worse if it had not been for the deliberate introduction of other species *O. esculentus* and other tilapiines and probably the accidental introduction of some haplochromine species now a major species of commercial importance from this lake. Although *P. aethiopicus* is not mentioned among those species introduced, the nature of its ecology favours it to have found its way into this system on its own.

Food and feeding of the major fish species in this lake has not seriously changed from what is expected. Trophic structure is well balanced with all individual species well supplied with the required food sources. The majority of haplochromines are insectivore feeding on the abundant aquatic insects available on the lake.

Fish species that could have been candidates for introduction to boost the fishery ie. *C. Gariepinus*, *O. niloticus* and other tilapiines are present. It is therefore not necessary to add more of the same species but what is needed is to manage the available stocks in order to enable build up of stocks for sustainable exploitation.

6.3 Fisheries exploitation

The survey of fisheries exploitation on Lake Nakivali revealed that the current fisheries were mainly dependent on species that were native to the lake, i.e. haplochromines and *P. aethiopicus* rather than the introduced tilapiines. It was apparent that the existing restrictions on fishing time and methods were contributing to sustainable harvest of haplochromines. The haplochromine fishery is likely to remain vibrant if the existing measures were strengthened further to avoid overfishing.

Recovery of the tilapia fisheries probably requires closure of the fishery with 3"-4" mesh size gillnets which are used in this fishery, for at least six months to allow the stocks to rebuild. Stocking with tilapia fry could enhance this process but will require good management measures to allow future natural regeneration.

6.5 Socio-economics

Fishing as major source of livelihood around Lake Nakivali is still primitive/ artisanal as the major fishery targeted does not have a large market/ demand low. This has greatly affected the socio- economic status of most Nakivali fishing dwellers.

The lake shoreline will continue to recede if encroachment on the wetland surrounding the lake is not checked.

6 References:

- APHA, (1995) Standard methods for the examination of Water and Wastewater. 19th Edition. Washington, DC.
- Greenwood, P.H. 1966. *The fishes of Uganda*. The Uganda society, Kampala. (2nd ed.). 131 pp.
- Greenwood, P.H. 1981. The haplochromine fishes of the east African lakes. Collected papers on their taxonomy, biology and evolution with an introduction and species index. New York. Cornell university press. 939 pp.
- Hillebrand H., Dürselen C-D., Kirschtel D., Pollinger U. & Zohary T. (1999) Biovolume calculation for pelagic and benthic microalgae. J Phycol 35, 403-424.
- Hughes, R.H., Hughes, J.S., 1992. A Directory of African wetlands. IUCN, Gland, Switzerland and Cambridge UK/ENEP, Nairobi, Kenya WCMC, Cambridge, UK. xxxiv. 820pp.
- Komarek, J. and Anagnostidis, K. (1999) Cyanoprokaryota, 1. Teil Chroococcales. Jena: Gustav Fischer. pp 225-236.
- Komarek, J. and Kling, H. (1991) Variation in six planktonic cyanophyte genera in Lake Victoria (East Africa). Algol. Stud. 61, 21-45.
- Krom, M. D. (1982) Spectrophotometric determination of ammonia: A study of a modified Bertholet reaction using salicylate and dichlorisocyanurate. Analyst 105, 305-316.
- Lake Victoria Fisheries Organization (LVFO) 2007. Standard Operating Procedures for Collecting Biological Information from the Fishes of Lake Victoria. SOP No 1, 45 pp.
- Mandahl-Barth, G. (1954) The Freshwater Mollusks of Uganda and adjacent territories. Sciences Zoologiques 32, 206 pp.
- Merritt, R. W. And Cummins, K. W. (1984) An introduction to the Aquatics insects of North America. Second Edition. Kendall Hunt, Dubuque, Iowa. 721pp.
- Müller, R. and Wiedemann, O. (1955) Die Bestimmung des Nitrations im Wasser. Vom Wasser 22, 247-271.
- Nagayi Kalule, J.F. 1999. Population characteristics of *Oreochromis esculentus* in satellite lakes of the Victoria and Kyoga Lake basins. *MSc. Dissertation* Makerere University 86pp.

- Pennak, R. W. (1953) Freshwater invertebrates of the United States. The Ronald Press Company, New York. 769 pp.
- Stainton, M. P., Capel, M. J. and Armstrong, F. A. J. (1977) The chemical analysis of Freshwater. Second Edition. Fish. Mar. Serv. Misc. Spec. Pul. 25, 166 pp.
- Talling, J. F. (1987) The phytoplankton of Lake Victoria (East Africa). Arch. Hydrobiol. Beih. Ergebn. Limnol. 25, 229-256.
- Wetzel, R. G. and Likens, G. E. (2000) Limnological analyses, 3rd edition. New York: Springer. 429 pp.
- Utermöhl H. (1958) Zur Vervollkommnung der quantitativen Phytoplanktonmethodik. Mitt Internat Verein Limnol 2, 1-38.
- Vanden Bossche, J.P., Bernacsek, G.M., 1990. Source book for the inland fishery resources of Africa Vol.1. CIFA Technical Paper 18/1. FAO, Rome, p. 240.
- Welcomme, R.L., 1999. A review of a model for qualitative evaluation of exploitation levels in multi-species fisheries. Fisheries Management and Ecology 6, 1-19.
- Worthington, E.B., 1932 A Report on the Fisheries of Uganda Investigated by the Cambridge Expedition to the East African Lakes 1932-33. Crown Agents for the Colonies, London.